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### CRITERION FOR PRIORIZATION OF THE BRAZILIAN ECONOMY SECTORS VIS-À-VIS THE CONSUMPTION OF ENERGY AND GENERATING SOURCES

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**Abstract.** *The objective of this paper is to establish a criterion for prioritizing sectors of the Brazilian economy vis-à-vis their consumption of energy and the generating sources meeting the demand. Based on a statistical analysis (bar graphs and Pareto diagram), the methodology conceived confirms that 50.0% of all ten sectors considered are responsible for 83.9% of the overall demand, where, industry; transportation, energy and residential are the critical sectors that most consumes. Among the main findings, the study shows that (i) highways —a subsector of transportation sector (ranked second)—, consumes 92.9% of the overall energy required by the sector, powered by Diesel oil (46.2%), Gasoline (30.9%) and Hydrated Alcohol (10.6%), therefore totalizing 87.7% of the energy used by this subsector. In contrast to other orthodox analyzes of the energy matrix, the proposed statistical analysis proved to be a practical energy planning tool to guide public policies aimed at rationalizing consumption and meeting the critical demands of the ever-growing energy needs of the country.*

**Keywords:** *Brazilian economic sectors, energy matrix, energy efficiency, energy consumption, Pareto principle*

## 1. INTRODUCTION

The energy matrix defines the set of resources required by a country to supply the energy needed to carry out its productive processes (Gomez, 2015). It involves all energy harnessed from every energy source applied towards the country's endeavors across every single industrial and technological sector (EPE, 2016). Two are types of resources available: (i) primary (e.g.: oil, natural gas and coal), understood as energy sources from nature (not undergoing transformation processes) and (ii) secondary (e.g.: gasoline, diesel, electricity), obtained from raw materials that undergoes transformations (Marcocchia, 2007).

The Brazilian energy matrix —National Energy Balance (*Balanço Energético Nacional*, BEN)—, annually prepared by the *Empresa de Pesquisa Energética* (EPE) and published by the Ministério de Minas e Energia, MME (Ministry of Mines and Energy), constitutes a fairly complete document, regularly published since 1970, widely used by both, the government and the private sector, instrumenting their planning and investment activities (Vichi & Mansor, 2009).

Figure 1 illustrates the actual Brazilian Energy Matrix. These data were recently published by the Energy Research Company (EPE, 2017) and synthesize energy supply as well as energy demand by the various sectors of the national economy. As shown, on the hand there exists a strong dependence on Petroleum and its derivatives (36.5%), on the other hand, less polluting energy sources, such as sugar cane (17.5%), slightly increased its energy production compared to that of 2015 (15.4%). This confirms that efforts to make the energy matrix increasingly sustainable have become important.

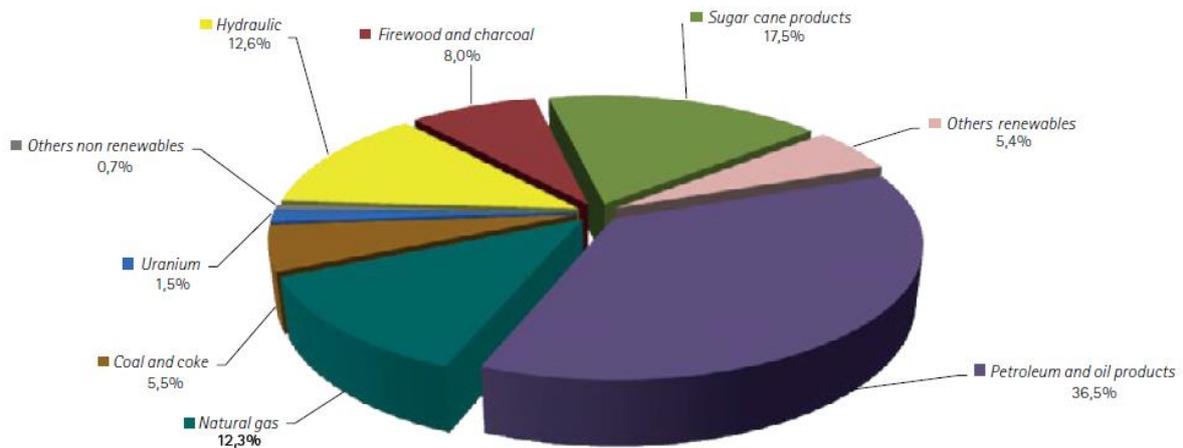


Figure 1. Brazilian Energy Matrix  
 REF: (EPE, 2017)

Figure 2 shows the official Brazilian electricity flux, largely dominated by hydroelectric power (64.0%), which relies on a consolidated infrastructure. Therefore, Figure 2 shows that *other clean energy sources* (e.g.: wind energy: 3.5%, biomass: 8.0%) have increased the production index in recent years, confirming the commitment of the Brazilian government policies to diversify the production of energy from a variety of sources (Silva & Vieira, 2016).

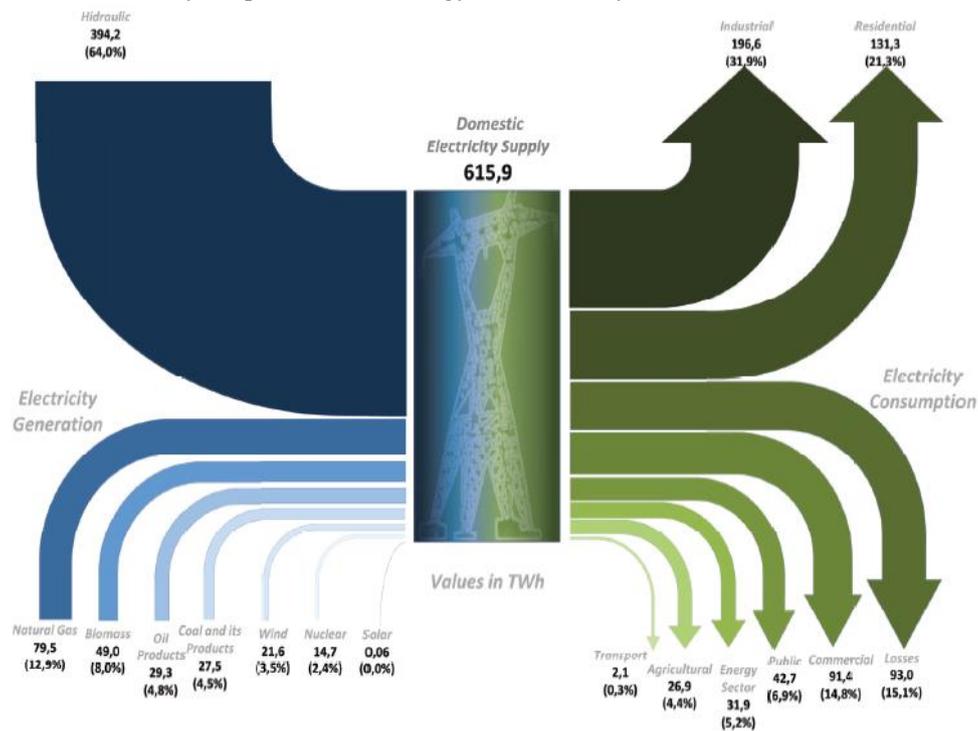


Figure 2. Brazilian electricity flux  
 REF: (EPE, 2016)

On the other hand, it is possible to verify that despite the generation of national electricity corresponds to an essentially hydraulic matrix (Lima, 2017), Figure 3 shows a dependence on fossil fuels (oil and derivatives) for the energy consumption.

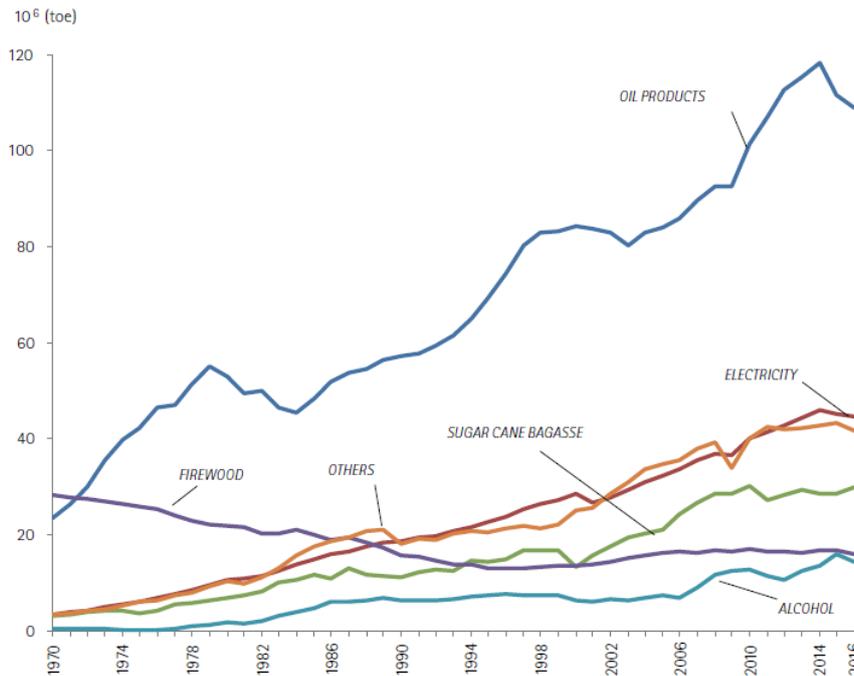


Figure 3. Final consumption by energy source in Brazil  
REF: (EPE, 2017)

Although in 2016 the production of energy in Brazil from petroleum products decreased by 15.8% in relation to the production of the previous year (EPE, 2016, 2017), it is also known that the substitution of oil by another energy is not a trivial goal to be achieved. Considering the negative impact caused to the environment for the future generations, major changes are required in both, generation and energy consumption

The motivation to developed this work emerged from the permanent effort to reduce the undesirable environmental effects that result from technological advances and energy consumption in critical sectors of the economy (*e.g.*: industry, transportation, residential, commercial, etc.). As universally advocated, energy efficiency becomes increasingly important as it pursues legitimate objectives of sustainability, *i.e.*: (i) mitigating environmental effects, contributing to the reduction of greenhouse gas (GHG) emissions and (ii) ensuring the future of the new generations.

## 2. METHODOLOGY

The methodology applied in this work encompasses the following stages (i) supply characterization; (ii) demand characterization; (iii) development of a statistical analysis, using bar graphs and Pareto diagrams (Randles & Wolfe, 1979) to account for the sectoral stratification (*i.e.*: Industrial, Transport, Public, Commercial, Agricultural, Non-energy, Residential and Energy). It is believed that all sectors considered are important for energy characterization, but not all are critical for strategic analysis to stimulate reduction of the national energy consumption.

Based on the Pareto principle (Randles & Wolfe, 1979), it was possible to identify the most critical sectors concerning energy consumption, understood in this work, as those responsible for at least 80.0% of the national energy consumption, taken as reference, the past two years (2014-2015). The importance of this mapping and sectoral stratification is based on the possibility of reducing a small percentage of energy in a sector of higher energy consumption (critical sector), than reducing a large percentage of a sector that requires little energy.

For example, a reduction of 1% in energy consumption in the industrial sector is equivalent to 846000 toe (tonne of oil equivalent). On the contrary, reducing 10% of the energy consumption of the public sector is equivalent to 400000 toe. Thus, from this perspective, one can conclude that a small reduction of the energy consumption (say, 1%) by the industrial sector would impact 53% on the energy gain.

## 3. RESULTS AND DISCUSSION

This section discusses the statistical analysis carried out to identify the most critical sectors (consumption of the overall 80% of the energy matrix) and sub-sectors of the Brazilian economy, *vis-à-vis* their overall energy consumption, taking into account official data made available by the National Energy Balance (EPE, 2016). This consumption represented 56.6% of Brazilian energy matrix into 2014-2015. Figure 4 illustrates the profile of energy consumption since 2005 up to 2015 for different sectors and Figure 5 shows the Pareto diagram for this situation.

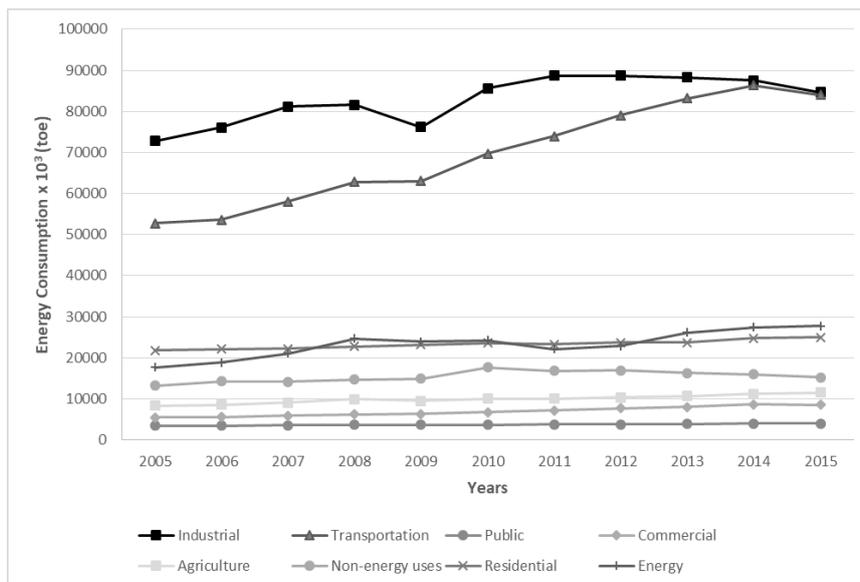


Figure 4 – Performance of energy consumption by sectors in Brazil

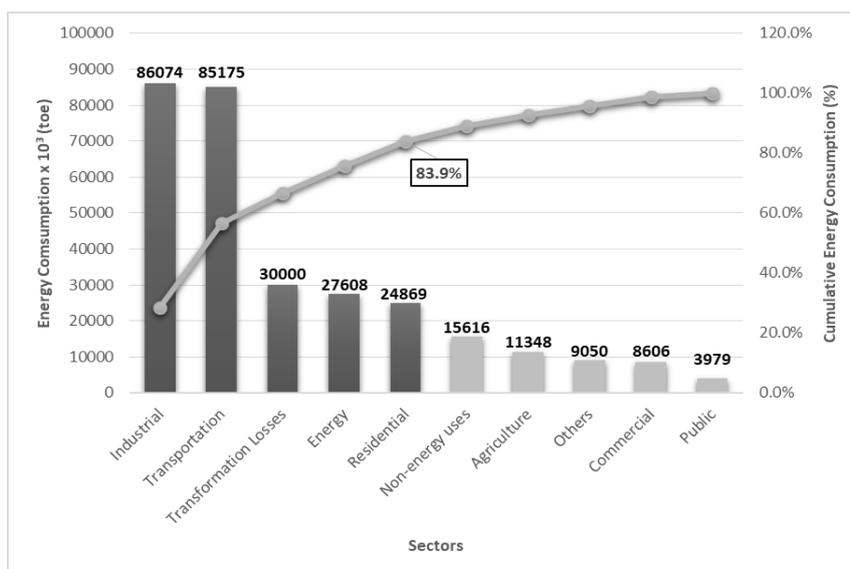


Figure 5 – Pareto diagram of energy consumption by sectors in Brazil

According to Figure 5 it is possible to conclude that 50.0% of the sectors in Brazil (*i.e.*: Industrial, Transportation, Transformation Losses, Energy and Residential) accounts for 83.9% of overall energy consumption. This is, certainly, a key information to guide efficiency energy policies. Evoking the principle of energy efficiency, one could say that efficiency actions implemented in the industrial sector would respond faster than similar actions applied to the commercial sector. The next section discusses results that allowed to identify the critical subsectors and sources of energy consumption in the transportation sector. The aim here is to apply the methodology to all Brazilian economic sectors, therefore allowing to identify relevant actions capable of inducing a reduction in energy consumption in Brazil.

### 3.1 Industrial Sector

This work considered for the statistical analysis the following subsectors of the industry according to data published by BEN (EPE, 2016), *i.e.*: Cement; Pig-Iron and Steel; Iron-Alloys; Mining and Pelletizing; Chemistry; Non-ferrous and other metallurgy; Textiles; Food and beverage; Pulp and paper; Ceramics; and Other industries. Table 1 presented the energy consumption of the industrial sector by sub-sector.

Table 1 - Energy consumption by industrial sector (x 10<sup>3</sup> toe)

Subsector / Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cement	2.902	3.129	3.444	3.820	3.778	4.255	5.033	5.135	5.287	5.338	4.744
Pig-Iron and Steel	16.914	16.446	17.664	17.627	13.008	16.445	17.401	16.914	16.274	16.387	16.725
Iron-Alloys	1.613	1.613	1.803	1.811	1.447	1.695	1.555	1.565	1.505	1.431	1.206
Mining and Pelletization	2.764	2.875	3.195	3.198	2.255	3.182	3.335	3.240	3.247	3.358	3.346
Chemistry	7.132	7.364	7.715	7.209	7.350	7.214	7.440	7.237	6.985	6.708	6.874
Non-ferrous and other metallurgy	5.403	5.668	5.954	5.966	5.353	6.492	7.074	7.057	6.935	6.616	5.646
Textiles	1.202	1.213	1.275	1.208	1.172	1.212	1.201	1.116	1.101	1.017	895
Food and beverage	17.926	20.122	21.262	20.694	21.547	23.244	22.992	24.123	23.338	22.238	21.475
Pulp and paper	7.713	8.016	8.555	8.957	9.346	10.131	10.195	10.003	10.574	11.173	11.729
Ceramics	3.412	3.533	3.841	4.193	4.128	4.485	4.724	4.803	5.069	5.079	4.614
Other industries	5.823	6.052	6.425	6.888	6.804	7.211	7.767	7.504	7.979	8.014	7.874

Figure 6 illustrates the Pareto Diagram of the energy consumption of the industry subsectors. Thus, it was possible to identify the critical sectors of the Brazilian economy, that is, those whose energy consumption corresponds to at least 80.0% of the consumption of the sector.

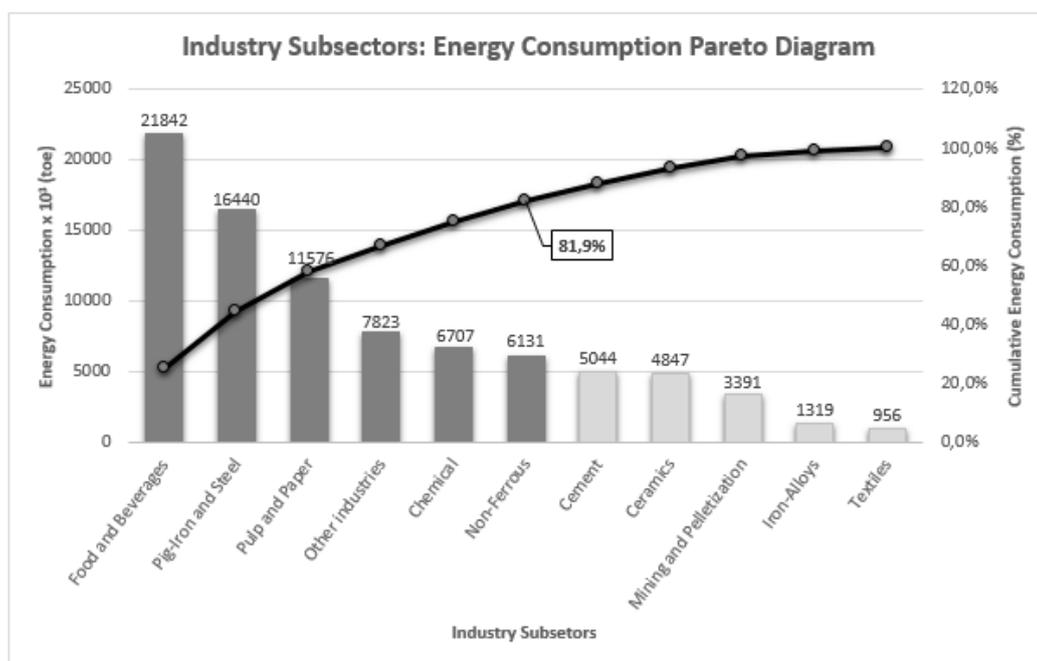


Figure 6 - Pareto diagram of energy consumption in the industrial sector

In the figure above it can be observed that 81.9% of the energy consumed in the industrial sector is concentrated in 6 of the 11 subsectors defined in the BEN. This makes it possible to identify that the critical sub-sectors of the industries are: (i) Food and beverages, (ii) Pig iron and Steel, (iii) Pulp and paper, (iv) Other industries, (v) Non-ferrous and other metallurgy. From this result, we identified the sources that represent at least 80.0% of the sources of consumption in each subsector of the industry. In this way, it is possible to apply energy efficiency criteria (Hernández-Vásquez, 2018).

### 3.2 Transportation Sector

The transportation sector ranks second in the list of all sectors which consume most energy in Brazil (28.2%), followed by the industrial sector (28.5%). According to BEN (EPE, 2016), this sector is sub-divided into four sub-sectors, *i.e.*: Highways, Railroads, Airways and Waterways. Table 2 summarizes the energy consumption of these subsectors, during a 10-year period (2005-2015).

Table 2 - Energy consumption by transportation sector (x 10<sup>3</sup> toe)

Subsector / Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
<b>Highways</b>	48073	49067	52892	57370	57683	63963	67896	72721	77007	79945	78267
<b>Railroads</b>	926	1040	1115	1149	1125	1135	1148	1190	1181	1173	1148
<b>Airways</b>	2596	2435	2674	2857	2874	3241	3623	3820	3667	3709	3658
<b>Waterways</b>	1124	1088	1338	1452	1359	1380	1323	1297	1298	1485	965

As clearly shown in Figure 7a, the sub-sector roadways (highways) accounts for the major part of the energy consumed by the transport sector. The Pareto analysis carried out, confirming this fact is giving by the data presented in Figure 7b.

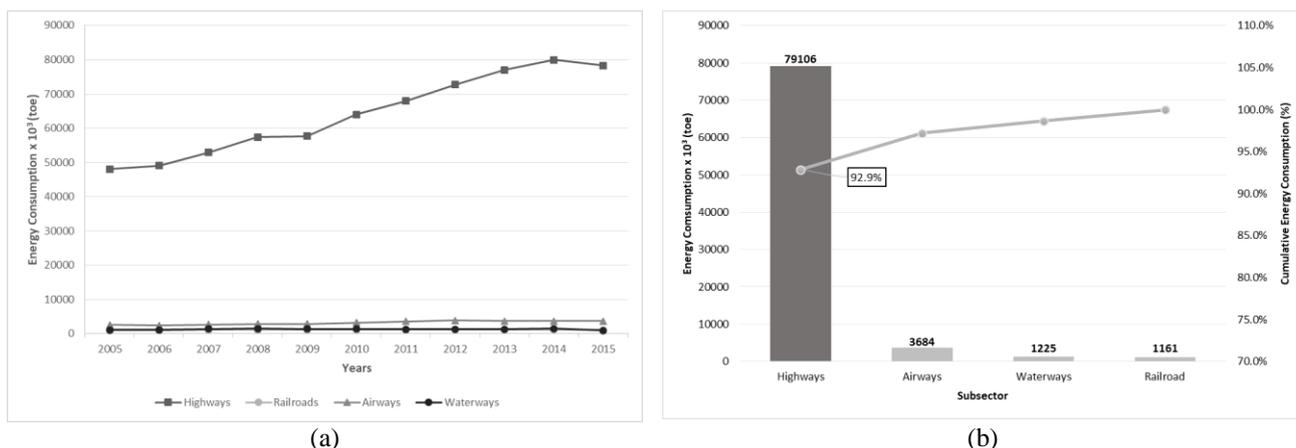


Figure 7 - (a) Profile of energy consumption; (b) Pareto diagram of energy consumption

The results confirmed that highways sub-sector is the most critical of the transportation' sectors. It demands 92.9% of the energy, compared to 4.3% of he Airways sub-sector and 1.4 % of the Waterways and Railroad sub-sectors. These results also allow further analyses, as summarized in Table 3.

Table 3 - Energy consumption by transportation sector (x 10<sup>3</sup> toe)

Subsector / Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Natural gas	1711	2030	2252	2158	1.853	1767	1735	1709	1647	1594	1553
Diesel oil	25803	26145	27406	28933	28345	31092	32859	34820	37123	37678	35371
Biodiesel	1	57	336	728	1019	1547	1729	1833	1954	1983	2662
Gasoline	13595	14440	14287	14538	14674	17525	20838	24454	24393	25682	23257
Anhydrous alcohol	4079	2777	3325	3533	3392	3790	4504	4144	5172	5882	5842
Hydrated alcohol	2885	3618	5287	7480	8400	8243	6230	5763	6717	7126	9582

Figure 8a illustrates all energy sources consumed by the Highways subsector. As shown, the largest energy consumption is associate to the use of diesel oil and gasoline. The application of the Pareto Principle, illustrate in Figure 8b, confirms that 50.0% of the overall sources (*i.e.*: diesel oil, gasoline and hydrated alcohol) represent 87.7% of the energy consumed by the Highways subsector.

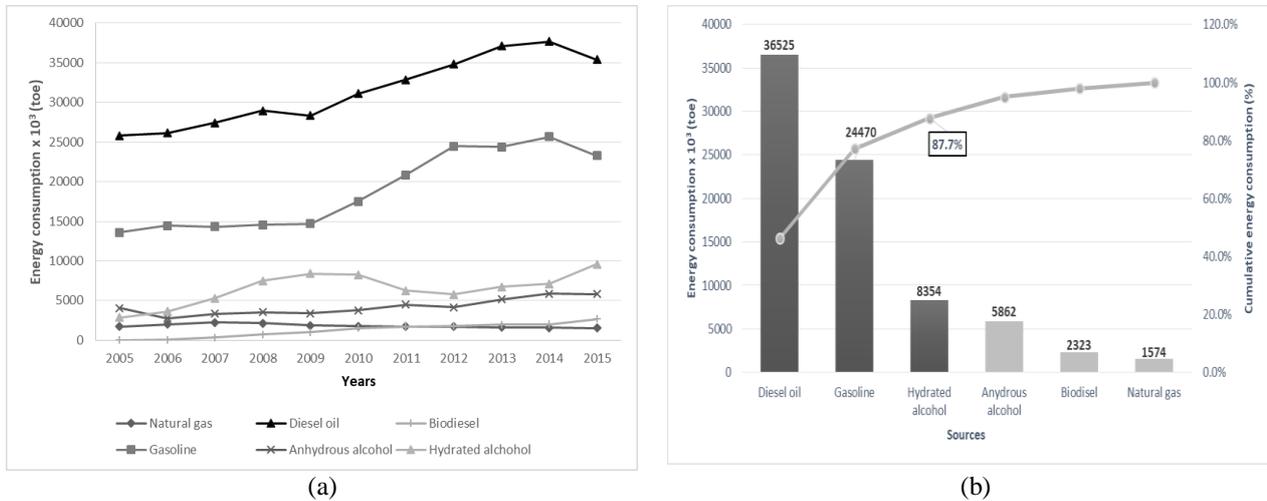


Figure 8 - (a) Profile of energy consumption by sources; (b) Pareto diagram of energy consumption by sources

### 3.3 Energy Sector

In general, the participation of the Brazilian energy sector currently corresponds to 9.3% of the national energy matrix, being located in the third place of the sectors of greater consumption. The demand, according to data from BEN (EPE, 2016) for the year 2015 was 27.763 x 10<sup>3</sup> toe.

The Brazilian energy sector has several sources of consumption, however, the demand is strongly concentrated on sugarcane bagasse as shown in Figure 9a. In addition, Figure 9b shows that 83.3% of energy demand is concentrated in only 37.5% of the sources (*i.e.*: sugarcane bagasse, natural gas, others oil products).

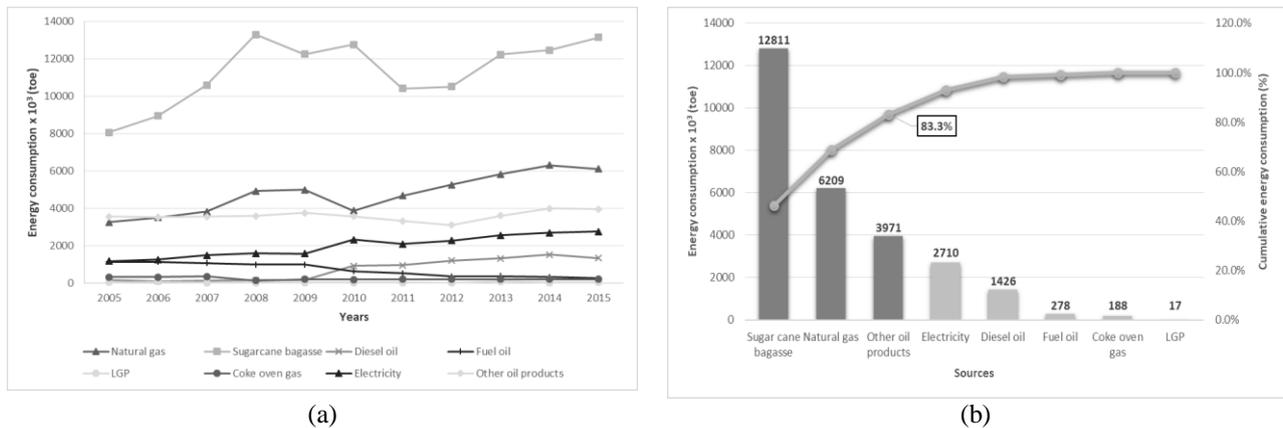


Figure 9 - (a) Profile of energy consumption by sources; (b) Pareto diagram of energy consumption by sources

Thus, in order to obtain a greater reduction of energy consumption in the sector, it is necessary to establish strategies of energy efficiency in the sources: sugarcane bagasse, natural gas and other secondary oil.

### 3.4 Residential Sector

The Brazilian Residential sector consumes three main sources of energy, *i.e.*: electricity, LPG and firewood. Figure 10a shows all sources of energy consumption by this sector, as declared by BEN (EPE, 2016). As shown, the consumption of electricity grows linearly over the last periods, except for the last two analyzed years (2014-2015) where a quasi-constant consumption happened. Application of the Pareto analysis (Figure 10b), confirms that 50.0% of all sectors consume 96.8% of the overall electricity sector.

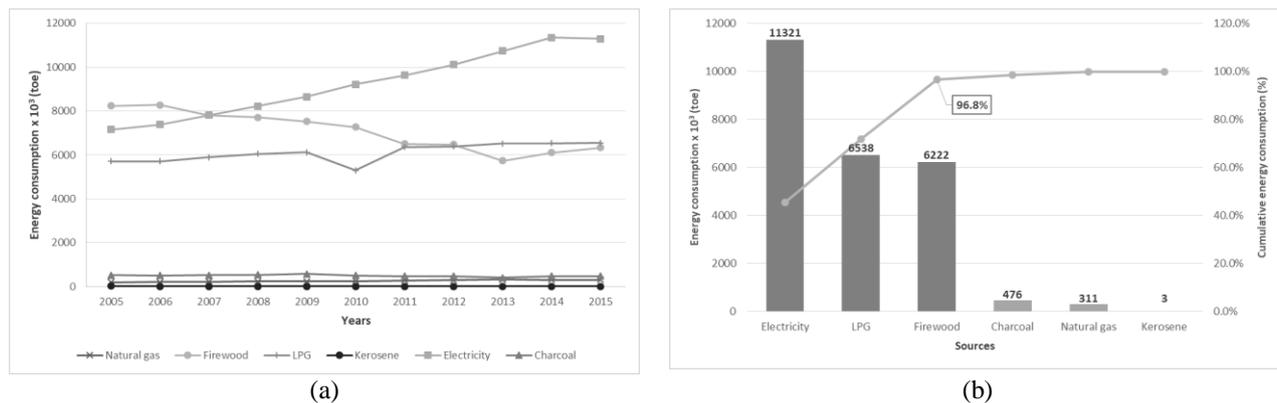


Figure 10 - (a) Profile of energy consumption by sources; (b) Pareto diagram of energy consumption by sources

These results clearly suggest strategic actions needed to improve electricity, LPG and Firewood energy sources, if a significant energy reduction of the energy consumption is desired.

#### 4. CONCLUSIONS

The statistical analysis conceived, based on bar graphs and Pareto diagrams, proved to be a practical and efficient energy tool to define basic criteria for prioritizing sectors of the Brazilian economy, when consumption of energy and generating energy sources are to be considered. The 80.0% criteria, used to identify the critical sectors, also proved to be a consistent threshold value to be used, as it yielded to consistent results. Based on the statistical analysis carried out, it was concluded that Industry (28.5%), Transportation (28.2%), Energy (9.1%) and Residential (8.2%) are the critical sectors of the Brazilian energy matrix. The energy consumption of these four sectors, together with the losses in transformation (9.9%), accounts for 83.9% of the overall national energy matrix. In addition, it was possible to establish that the subsector Highways accounts for 92.9% of the energy demand of the transportation sector. Diesel oil (46.2%), gasoline (30.9%) and hydrated alcohol (10.6%) were identified as the main sources of energy consumed by the Highways subsector. Concerning the Energy sector, sugar cane bagasse (46.4%), Natural gas (22.5%) and other oil products (14.4%), were identified as the most relevant. These sources represent 83.3% of the energy demand by the sector. Finally, for the Residential sector, electricity (45.5%) continues to be the main source of energy consumed in Brazil, followed by LPG (26.3%) and firewood (25.0%).

The industrial sector represents 28.5% of the national energy demand, accounting for the largest energy consumption in the country.

The methodology here in discussed offered a workable and practical alternative to assess the energy matrix and to create criterion for prioritizing sectors of economy responsible for most of the energy consumption, while evaluating the critical generating sources, therefore useful for guiding energy public policies.

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